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ESTIMATES OF DOUGLAS FIR PRODUCTIVITY FOR SEVERAL SOUTHWESTERN HABITAT TYPES, INCLUDING THE EFFECTS OF DWARF MISTLETOE INFECTION.

Estimates of Douglas-fir Productivity for Several Southwestern Habitat Types, Including the Effects of Dwarf Mistletoe Infection

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Estimates of Douglas-fir Productivity for Several Southwestern Habitat Types, Including the Effects of Dwarf Mistletoe Infection

Abstract: Estimates of potential timber productivity for Douglas-fir based on site indexes, ten-year periodic annual increments, and mean total periodic annual increments were compared between several southwestern habitat types. Significant differences in productivity were found between many of the habitat types studied. However, the above methods produced relatively inconsistent estimates of Douglas-fir productivity. Ten year periodic annual increment for dominant and codominant trees is proposed as the best method for estimating potential timber productivity for Douglas-fir by habitat type.

Ten-year periodic annual increment was not significantly different between healthy and lightly infected Douglas-firs in any habitat type. Heavy dwarf mistletoe infection caused significantly lower volume growth when compared to healthy and lightly infected trees in every habitat type. Moderate infection caused significantly lower volume growth in two habitat types. In addition, the degree of volume growth reduction for moderately and heavily infected Douglas-firs varied greatly between habitat types.

Management Implications

Estimates of potential fiber production based on ten-year periodic annual increment for dominant and codominant Douglas-firs vary significantly between several southwestern habitat types. Although these estimates are not precise, they indicate that habitat type is a potentially good indicator of fiber production for Douglas-fir in the Southwest. As management of southwestern mixed conifer forests intensifies, stands representing those habitat types with higher productivity potentials should be given management priority.

Certain habitat types have higher potential for damage from dwarf mistletoe infection. Therefore, mistletoe control should be a primary concern of the land manager in those habitat types. Although moderate infection of Douglas-firs caused significant growth reductions in only two of the habitat types studied, moderate infection does reduce growth and moderately infected trees should be removed from stands whenever possible. Heavy dwarf mistletoe infection causes significant growth loss regardless of the habitat type, and the removal of heavily infected trees from infested stands should always be a primary objective during all stand entries.

Introduction

During the last decade the use of habitat types (Daubenmire 1952) to classify forest vegetation has gained increasing acceptance by land managers and researchers in the western United States (Layser 1974, Pfister 1976, Pfister and Arno 1980). One of the primary uses of habitat types has been in timber management. Habitat types have been used for comparing regeneration success, succession patterns, cutting methods, timber productivity, and for the development of guidelines for seed collection and planting of nursery stock (Pfister and Arno 1980).

The use of habitat types to predict forest site productivity potential has been proposed by several investigators. Differences in the rate of height growth by habitat type have been demonstrated for several tree species (Daubenmire 1961, Deitschman and Greene 1965, Stanek 1966, Stage 1975, Hoffman 1976). Significant differences between site indexes have been shown for habitat types also (Stanek 1966, Stage 1975, Hoffman 1976). Pfister et al. (1971, 1977) and Steele et al. (1981) used site index curves and normal yield tables to estimate yield capability for habitat types in Montana and Idaho.

Southwestern forests are becoming more intensively managed for timber production, but growth and productivity data are presently limited (Gottfried 1978). Habitat type classifications have been developed for the forests, but little information is available on the timber productivity potential for the recognized habitat types (Moir and Ludwig 1979, Hanks et al. 1983, Alexander et al. 1984). Jones (1974) provided a summary of the silviculture of southwestern mixed conifer forests and emphasized a need for improving their management based on the application of habitat types or stand types. In addition, he pointed to the need for obtaining additional information on the effects of dwarf mistletoes (Arceuthobium spp.) on these forests.

Douglas-fir dwarf mistletoe (Arceuthobium douglasii Engelm.) is the most prevalent and damaging disease agent in southwestern mixed conifer forests (Andrews and Daniels 1960, Hawksworth and Wiens 1972, Jones 1974). It occurs in all southwestern national forests, causing increased mortality and decreased growth of Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco), the most abundant and commercially valuable mixed conifer species in the Southwest. However, few quantitative data are available on the effect of this parasite has Douglas-fir timber productivity in infested southwestern forests. Dwarf mistletoe infection significantly reduces volume growth of stands (Hawksworth and Scharpf 1978). Because growth losses vary with infection intensities, age distributions, stand compositions, and site quality (Pierce 1960, Parmeter 1978), the effects of dwarf mistletoe infection on timber productivity may vary by habitat types.

This paper reports Douglas-fir timber productivity estimates for several southwestern spruce-fir and mixed conifer habitat types based on Douglas-fir site index measurements and ten year periodic annual volume increments on a tree and stand basis. In addition, the effects of Douglas-fir dwarf mistletoe infection on mean periodic annual increment of Douglas-fir are compared between habitat types.

Methods

Douglas-fir Growth Data Collection:

Douglas-fir growth data was collected from southwestern spruce-fir and mixed conifer stands in Arizona and New Mexico from 1979 to 1981. In 1979, 150 temporary rectangular 0.2 acre plots were completed in the Apache-Sitgreaves National Forest, Arizona. The following information was recorded for each stand sampled: location (township, range, and section), elevation

(nearest 100 feet), aspect (four cardinal directions), slope (nearest five percent), slope position (upper one-sixth, middle two-thirds, lower one-sixth), stand history (cut, burned, virgin), approximate date of disturbance (when applicable), and habitat type (Moir and Ludwig 1979). The following data was recorded for each tree greater than 4.5 feet in height in each plot:

1. Diameter at breast height (DBH) of all trees (Douglas-fir by one-inch DBH classes, other species by two inch DBH classes).

2. Height and age of four Douglas-firs from each one-inch DBH class (nearest 1.0 foot).

3. Six-class dwarf mistletoe rating (DMR, Hawksworth 1977).

4. Radial growth at DBH for the last five and ten years (to the nearest 0.05 inch) for three Douglas-firs from each age class and DMR class represented.

5. Total height and age at DBH for four to six vigorous dominant or codominant Douglas-firs (DMR less than 2) for determination of site index (Edminster and Jump 1976). Site trees were selected from outside the plot when necessary, but within the same habitat type.

Approximately 11,000 Douglas-firs were examined in the 1979 plots.

Data collection procedures were revised in 1980 and 1981 to provide additional growth data for all species in the field plots. Stand data gathered was basically the same as in 1979, but plot size was density dependent because each plot was to include approximately 150 live trees greater than 4.5 feet in height. The following data was recorded for each plot:

A. All trees greater than 4.5 feet in height:

1. Species

2. DBH (nearest 0.1 inch).

3. DMR (six-class system).

4. Crown class (dominant, codominant, intermediate, suppressed) and mortality rating (dead 0-5 years, dead 6-10 years, dead over 10 years).

5. Five and ten year past radial growth at DBH for trees greater than 0.5 inch DBH (nearest 0.05 inch).

B. Selected trees.

1. Total height of two to three living or dead trees from each one inch DBH class for each species occurring in a plot (nearest 1.0 foot).

2. Height to base of live crown for live trees measured for height (nearest 1.0 foot).

3. Distance from the ground to the fifth and tenth whorls from the top of live trees measured for height (nearest 1.0 foot).

4. Age at DBH for two live trees from each two-inch DBH class for each species present in a plot.

5. Total height and DBH age for three to six vigorous dominant or codominant Douglas-firs for site index determination.

In 1980, 100 temporary growth plots were completed in spruce-fir and mixed conifer stands in the Lincoln (57 plots) and Carson (43 plots) National Forests, New Mexico. Approximately 7,000 Douglas-firs were sampled for growth. One hundred thirty-seven growth plots were completed in 1981 on the Apache-Sitgreaves (98 plots), Santa Fe (27 plots), and Kaibab (12 plots) National Forests. These plots provided additional growth data for approximately 9,000 Douglas-firs. A total of nine habitat types were sampled (Appendix A).

Growth Data Analyses:

Mean site indexes, standard deviations, and 95 percent confidence intervals were calculated for each habitat type sampled (1979-1981) using Douglas-fir site index data. A one-way analysis of variance (ANOVA), with $p = 0.10$, was used to compare mean site indexes among habitat types. The Least Significant Difference (LSD) multiple range test was applied to the analyses to show where significant differences occurred.

Means and standard deviations were calculated for total basal area, Douglas-fir basal area, and Douglas-fir live standing volume by habitat type using data from all of the sampled stands. Douglas-fir volumes were calculated using volume equations developed by Hann and Bare (1978). Data were compared by habitat type using a one-way ANOVA ($p = 0.10$). An LSD multiple range test was used to determine where significant differences occurred.

Present and ten-year past volumes were calculated for living Douglas-firs with DBH greater than 6.0 inches (Hann and Bare 1978). Ten year periodic annual increment (PAI) was then calculated for each tree by plot. Mean ten year periodic annual increment (MPAI) and standard deviations were determined for dominant, codominant, and intermediate trees by DMR classes 0, 1-2, 3-4, and 5-6 by habitat types. In addition, dominant and codominant trees were combined in DMR classes 0, 1-2, 3-4, and 5-6 and MPAIs were calculated by habitat type. Standard deviations and 95% confidence intervals were determined for each MPAI calculated.

A one-way ANOVA ($p = 0.10$) was used to detect significant differences in MPAI between each habitat type and between DMR classes for each habitat type. The LSD multiple range test was used to determine where differences occurred. Following initial data analyses, DMR classes 0 and 1-2 were

combined in all crown classes because MPAI values were not significantly different at the 0.10 level.

Growth differences between DMR classes were also expressed as a percentage using the following formula:

Percent Difference (PD) = MPAI(DMR X)/MPAI(DMR Y) * 100. Percent growth reduction from one DMR class to another was calculated as follows:

Percent Growth Reduction (PGR) = 100 - PD.

Ten year periodic annual increments of dominant, codominant, and intermediate Douglas-firs (DMR 0-6) were summed by plot to arrive at a total periodic annual increment (TPAI) value for each plot. Mean total periodic annual increment (MTPAI) for each habitat type was calculated by averaging plot totals. The MTPAIs were calculated with dwarf mistletoe-infested and noninfested plots combined and again using only noninfested plots.

A one-way ANOVA ($p = 0.10$) was used to detect significant differences in MTPAI between habitat types. The LSD multiple range test was used to determine where differences occurred.

Results

Site Index:

The twelve habitat types sampled were divided into three groups based on mean site indexes (high, moderate, and low site quality) (Figure 1). Three habitat types were classified as having high mean site indexes which ranged from 92.3 for the ABCO-PSME/ACGL; HODU Ph. habitat type to 88.9 for the PIPU-PIEN/SECA habitat type. The moderate mean site index group included seven of the habitat types studied and ranged from 79.5 for the PIPU-PSME habitat type to a low of 71.9 for the ABLA/VASC-LIBO habitat type. The low mean site index group included the ABCO-PSME; BERE Ph. and ABCO-PSME/ACGL; BERE Ph. habitat

types. Mean site indexes, significant differences, and the range of site indexes for each habitat type are presented in Table 1.

Basal Areas:

Mean Douglas-fir basal area and mean total basal area are presented for each habitat type in Table 2. The range for mean Douglas-fir basal area was 201.7 to 72.7 square feet/acre. Mean total basal area ranged from 310.5 to 110.0 square feet/acre. No distinct groups were found, rather there appeared to be a continuum for both Douglas-fir and total basal areas. Habitat types with high to moderate site indexes and high Douglas-fir live standing volumes were intermixed along the continuum of mean basal areas. The ABCO-PSME/ACGL; BERE Ph. habitat type had the lowest mean site index, basal areas, and live standing Douglas-fir volume.

The percent of total basal area which was represented by Douglas-fir basal area is shown by habitat type in Table 2 also. Douglas-fir basal area represented 73% of the mean total basal area in the ABLA/VASC-LIBO habitat type and went as low as 19% in the ABCO-PSME/QUGA habitat type. The majority of the percentages were clumped in the mid to high 60 percentile.

Douglas-fir Live Standing Volume:

Statistically significant differences were found in Douglas-fir live standing volume among the habitat types sampled (Table 3). Mean volumes ranged from 5184.5 to 966.3 cubic feet/acre.

Periodic Annual Increment:

Ten-year periodic annual increment (PAI) for dominant, codominant, and intermediate Douglas-firs were significantly different ($p = 0.10$) in all habitat types studied regardless of their DMR class. Because no significant differences in PAI were found between healthy trees (DMR 0) and lightly

infected trees (DMR 1-2) for each crown class, these DMR classes were combined when PAI was computed for each habitat type. Periodic annual increment for dominant, codominant, and intermediate Douglas-firs (DMR 0-2) ranged from 1.93 to 4.20, 1.16 to 1.93, and 0.12 to 0.33 cubic feet/acre/year, respectively (Table 4). Relatively large variation occurred for PAI in each crown class by habitat type. The greatest amount of variation occurred in the intermediate crown class where standard deviations were greater than means. Although sample sizes were smaller for dominant and codominant trees, there was relatively less variation in PAI for those crown classes.

Periodic annual increment for dominant Douglas-firs by DMR classes (0-2, 3-4, and 5-6), and habitat types is presented in Table 5. The following habitat types did not have significant differences ($p = 0.10$) in PAI for dominant trees between DMR classes 0-2 and 3-4, but did have significant differences in PAI between DMR classes 3-4 and 5-6: PIPU-PIEN/SEGA, ABCO-PSME/QUGA, ABCO-PSME; BERE Ph., ABCO-PSME/ACGL; HODU Ph. and BERE Ph., and ABLA/VASC-LIBO. Habitat types with significant differences between each DMR class were ABLA/ERSU, PIPU-PIEN/ERSU, ABCO-PSME; RONE Ph., ABCO-PSME/ERSU, and PIPU-PSME; VAAC Phase. The ABCO-PSME/POFE habitat type had significant differences in PAI between DMR classes 0-2 and 3-4, but not between DMR classes 3-4 and 5-6. The pattern of significant differences between DMR classes for codominant trees was different than for dominant trees for some of the habitat types (Table 6). No significant differences were found between DMR classes for intermediate trees in any of the habitat types (Table 7).

The results of computing PAI by combining dominant and codominant Douglas-firs (DMR 0-2) are presented in Table 8. Potential productivity by habitat type for dominant and codominant Douglas-firs based on PAI were grouped into three relative productivity classes (Figure 2). The 95%

confidence intervals for the ABCO-PSME/ACGL; HODU Ph. and ABCO-PSME/POFE habitat types extended into the moderate productivity class.

Table 9 presents computed PAI for the combined dominant and codominant trees by DMR classes (0-2, 3-4, and 5-6) and habitat type. Nine of the 12 habitat types had no significant differences ($p = 0.10$) in PAI between DMR classes 0-2 and 3-4, but did have significant differences between DMR classes 3-4 and 5-6. The PAI's of the PIPU-PIEN/ERSU and ABCO-PSME; RONE Ph. habitat types were significantly different between each DMR class (Table 9). The PAI's of DMR class 0-2 and 5-6 were significantly different in the ABCO-PSME/ACGL; BERE Ph. habitat type.

Growth reduction due to mistletoe infection, as expressed as a percentage of potential PAI by DMR classes 3-4 and 5-6 is shown in Table 10 for each habitat type. Growth reductions for DMR class 3-4 ranged from 0% (no reduction or greater growth) to 31%. Comparison, using the analysis of variance (ANOVA) test, indicated that growth reductions less than 20% were significant (compare Tables 9 and 10). Reductions for DMR class 5-6 ranged from 45% to 65% for 10 of the habitat types. The ABCO-PSME; BERE Ph. habitat type had the greatest growth reduction (75%). The ABCO-PSME/QUGA habitat type had a much lower growth reduction for DMR 5-6 (24%) than any of the other habitat types. A rating representing relative potential damage due to dwarf mistletoe infection was obtained for each habitat type by adding potential growth reduction for moderately and heavily infected trees (Table 10).

Total Periodic Annual Increment:

Values for total periodic annual increment (TPAI) calculated by combining data from noninfested and mistletoe-infested plots were lower than values calculated using noninfested plots only for all habitat types. However, none of the differences were statistically significant at the 0.10 level (Appendix

B). Total periodic annual increment for noninfested plots by habitat type is presented in Table 11. Values ranged from a high of 66.3 cubic feet/acre/year for the ABCO-PSME/ERSU habitat type to a low of 35.3 cubic feet/acre/year for the ABLA/ERSU habitat type. There were no significant trends in productivity as expressed by TPAI for the habitat types sampled. Six habitat types had TPAIs that were not significantly different from that of the ABCO-PSME/ERSU habitat type and seven were not significantly different from the ABLA/ERSU habitat type.

Figure 3 presents mean, maximum, and 95% confidence intervals for TPAI for noninfested plots for those habitat types having sample sizes of five plots or more. Variation in 95% confidence intervals ranged from approximately 10 to 35 cubic feet/acre/year. Comparison with the yield capability classes designated by Pfister et al. (1977) indicated yield capability for Douglas-fir is low to moderate in the Southwest.

Discussion

Site index is currently the most widely used method of evaluating site quality in the United States (Jones 1969, Husch et al. 1972). A few investigators have examined site indexes between habitat types for several tree species and found significant differences (Stanek 1966, Roe 1967, Hoffman 1976). However, Daubenmire (1961) rejected the use of ponderosa pine site index curves for predicting potential productivity for habitat types in eastern Washington.

Our results indicate there are significant differences in Douglas-fir site indexes between several southwestern spruce-fir and mixed conifer habitat types and that the habitat types can be grouped into three fairly distinct site quality classes for Douglas-fir. Although variability in site index was

relatively large for the habitat types with lower site quality ratings (ABLA/VASC-LIBO and ABCO-PSME; BERE Ph.), most of the habitat types had fairly low variability and 95% confidence intervals did not extend into other site quality classes. Hoffman (1976) also demonstrated significant differences in Douglas-fir site index between three habitat types in central Idaho.

In their descriptions of southwestern spruce-fir and mixed conifer habitat types, Moir and Ludwig (1979) gave estimates of site quality for individual tree species for several habitat types. Their estimates were based on site index and height-age data. Our site index and height-age data supports Moir and Ludwig's site quality estimates for Douglas-fir in the PIPU-PIEN/SECA (high potential), PIPU-PIEN/ERSU (moderate potential), ABCO-PSME/ACGL; BERE Ph. (low potential), ABCO-PSME; RONE Ph. (usually moderate potential), and the ABCO-PSME; BERE Ph. (low potential) habitat types. Our data also confirms their suggestions that the ABCO-PSME/ACGL; HODU Ph. and PIPU-PSME; VAAC Ph. habitat types have higher Douglas-fir growth potential than other phases in those habitat types.

Moir and Ludwig (1979) interpreted heights of 75-100 feet in 100 years (breast height age) for the fastest growing Douglas-firs in the ABCO-PSME/QUGA habitat type to represent poor to moderate site quality, whereas we would interpret this data as representing moderate to high site quality for the Southwest. Our site index data for this habitat type basically corresponds to that of Moir and Ludwig's, but we obtained a greater range in site indexes. However, site quality for Douglas-fir in the ABCO-PSME/QUGA habitat type will usually be moderate.

Moir and Ludwig (1979) did not present Douglas-fir site quality estimates for three of the habitat types sampled in this study. Based on our site index data, site quality for Douglas-fir is moderate for the ABCO-PSME/ERSU and

ABLA/ERSU habitat types and high for the ABCO-PSME/POFE habitat type.

Ten-year periodic annual increment for dominant, codominant, and intermediate Douglas-firs is significantly different in several southwestern habitat types. But for management considerations it would be more appropriate to use an average PAI obtained by combining dominant and codominant trees as an estimate of potential productivity of habitat types. When this approach was used there were significant differences in PAI between habitat types, but with a gradual change in PAI and with overlapping of 95% confidence intervals. Nevertheless, the significant differences in PAI detected between habitat types indicates habitat type is a good indicator of potential productivity for Douglas-fir in the Southwest.

Because trees growing in uneven-aged stands can have large variations in growth depending on several factors (Curtis 1976,) productivity estimates based on periodic annual increment for short periods of time can be misleading. Pfister et al. (1977) and Steele et al. (1981) used site index curves and normal yield tables to estimate yield capability on a stand basis for habitat types in western Montana and central Idaho. Because normal yield tables are not available for Douglas-fir in the Southwest, this method could not be used here. However, our method of totaling PAI for all trees in a plot and averaging totals by habitat type does provide a rough estimate of yield capability for habitat types on a stand basis. Comparison of yield capability for southwestern spruce-fir and mixed conifer habitat types sampled in this study, with the yield capability classes established by Pfister et al. (1977), indicates that productivity for Douglas-fir gradually increases from the low into the moderate yield capability class (Figure 3). However, maximum values for four of the habitat types fell in the high yield capability class.

Because our method of estimating yield capability for Douglas-fir by

habitat type was highly dependent on stand density and size distribution, there was large variability in our results. Ninety-five percent confidence intervals ranged from approximately 10 to 35 cubic feet/acre/year. However, variability in yield capability estimates was even greater for the method used by Pfister et al. (1977) and Steele et al. (1981, 1983) where estimates varied by 30 to 60 cubic feet/acre/year for most habitat types. It should also be noted that our yield capability estimates used Douglas-fir data only, whereas Pfister et al. and Steele et al. used site trees for several species within each habitat type, which would be expected to produce more variability.

Since we did not include PAI for other species in our estimates of yield capability, our estimates do not represent total yield potential for the habitat types. Inclusion of other species, such as white fir, blue spruce, Engelmann spruce, and ponderosa pine would increase our yield capability estimates and would probably move several of the habitat types into higher yield capability classes.

Comparison of estimates of site quality (site index) and potential productivity for each habitat type indicates that these two methods do not give similar results for several of the habitat types studied. Some habitat types with high mean site indexes had PAIs for dominant and codominant trees that fell in the moderate productivity class. Other habitat types with low mean site indexes had PAIs in the high productivity class (compare Figures 1 and 2).

Considering the difficulties related to using site index for estimating site quality in uneven-aged stands (Stage 1963, Jones 1969, Curtis 1976, Daubenmire 1976), the use of ten year periodic annual increment (current volume growth) for dominant and codominant Douglas-firs is probably the best

method presented here for estimating potential productivity by habitat type. Although climatic fluctuations and differences in stand structure can influence volume growth over short periods of time in uneven-aged stands (Curtis 1976), the use of PAI based on growth measurements from dominant and codominant trees for ten year periods or more should greatly reduce the variation in PAI and give fairly representative estimates of potential productivity for habitat types. Steele et al. (1981, 1983) suggest this method is preferable to basing productivity estimates on site index which can be extremely inaccurate and variable in uneven-aged stands and normal yield tables which are based on averages. The development of separate site curves for different habitat types could improve the accuracy of site index as an estimate of site quality. However, this approach may not solve the problems related to using site index in uneven-aged stands such as early suppression of shade tolerant species (Vincent 1961, Curtis 1976). We agree with the suggestion of Steele et al. (1981, 1983) that the development and subsequent validation of growth and yield simulation models using growth coefficients based on habitat types (Stage 1973, 1975) should greatly improve productivity estimates for different habitat types.

Comparison of significant differences in PAI and percent growth reduction between habitat types indicates the impact of dwarf mistletoe infection on Douglas-fir productivity varies between habitat types. Habitat types in which moderately infected trees (DMR 3-4) had significantly lower PAIs as compared to healthy or lightly infected trees (DMR 0-2) are those habitat types with the highest potential for serious damage as a result of mistletoe infection. Significant growth reductions will occur at lower infection levels and be greater over time in habitat types with relatively high damage potentials. Therefore, mistletoe control in these habitat types should be given high priority by land managers.

There does not appear to be a direct correlation between habitat types having the highest productivity potentials and those having the highest damage potentials. Daubenmire (1961, 1969) suggests that dwarf mistletoe infection of ponderosa pine may be associated with specific habitat types because they represent low site potential. Merrill (1983) demonstrated more frequent and severe dwarf mistletoe infection of ponderosa pine for habitat types representing the more xeric communities of the ponderosa pine series in Colorado. However, the relationship between dwarf mistletoe prevalence or intensity of damage and site quality is not well understood (Parmeter 1978).

Although the results of this study indicate there are significant differences in the damage caused by Douglas-fir dwarf mistletoe in different habitat types, heavy mistletoe infection always causes large growth losses. Therefore, removal of heavily infected Douglas-firs should always be a primary objective of land managers during stand entries, regardless of the habitat type.

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Table 1. Mean Douglas-fir site indexes and ranges by habitat type.

Habitat Type	Number Of Stands	Mean	Site Index by 10 Foot Classes 41-50	51-60	61-70	71-80	81-90	91-100	101-110
ABCO-PSME/ACGL; HODU Ph.	12	92.3 ± 7.1 A 1/	0	0	0	0	8	2	2
ABCO-PSME/POFE	10	89.7 ± 3.3 A	0	0	0	0	8	2	0
PIPU-PSME/SECA	17	88.9 ± 10.4 A	0	0	0	4	5	7	1
PIPU-PSME; VAAC Ph.	16	79.5 ± 10.6 B	0	1	2	3	9	1	0
PIPU-PIEN/ERSU	25	77.5 ± 9.9 B	0	0	8	8	7	2	0
ABCO-PSME/QUGA; TYP. Ph.	29	77.2 ± 10.5 B	0	1	7	13	6	0	2
ABCO-PSME/ERSU	10	76.3 ± 9.9 B	0	1	3	2	4	0	0
ABCO-PSME; RONE Ph.	39	75.7 ± 9.7 B	0	1	14	15	4	5	0
ABLA/ERSU	12	73.6 ± 10.7 B	0	2	5	1	4	0	0
ABLA/VASC-LIBO	8	71.9 ± 16.1 B	0	3	1	2	1	1	0
ABCO-PSME; BERE Ph.	5	58.6 ± 8.9 C	1	3	0	1	0	0	0
ABCO-PSME/ACGL; BERE Ph.	8	56.4 ± 3.2 C	0	7	1	0	0	0	0

1/ Oneway AOV, p = 0.10, LSD multiple range test. Means followed by different letters are significantly different.

Table 2. Mean basal areas and percent total basal area represented by Douglas-fir habitat type.

Habitat Type	Number Plots	Mean Basal Area (ft^2/acre) Douglas-fir	Total	Percent Douglas-fir Basal Area of Total Basal Area
ABLA/ERSU	25	201.7 ± 66.2	297.4 ± 70.2	68
PIPU-PIEN/SECA	38	198.0 ± 87.9	310.5 ± 73.9	64
PIPU-PIEN/ERSU	62	165.1 ± 62.4	240.8 ± 65.3	69
ABLA/VASC-LIBO	12	160.7 ± 37.9	219.9 ± 51.9	73
ABCO-PSME/ERSU	16	158.6 ± 66.3	251.2 ± 51.9	63
ABCO-PSME/POFE	26	156.8 ± 54.7	218.0 ± 52.5	72
PIPU-PSME; VAAC Ph.	28	150.3 ± 59.1	215.4 ± 57.3	70
ABCO-PSME; Both Ph.	81	129.2 ± 61.5	238.0 ± 66.0	54
ABCO-PSME/ACGL; HODU Ph.	26	122.4 ± 43.7	210.5 ± 63.1	58
ABCO-PSME/QUGA; TYP. Ph.	47	91.8 ± 43.8	188.7 ± 36.8	49
ABCO-PSME/ACGL; BERE Ph.	3	72.7 ± 40.2	110.0 ± 34.0	66

Table 3. Mean Douglas-fir standing volumes by habitat type.

Habitat Type	Number Plots	Mean Volume 1/	
PIPU-PIEN/SECA	38	5184.4 ± 7072.2	A 2/
ABCO-PSME/POFE	26	4044.9 ± 1381.3	B
ABLA/ERSU	25	3936.7 ± 2129.2	B
PIPU-PIEN/ERSU	62	3891.8 ± 1745.7	B
ABCO-PSME/ERSU	16	3191.9 ± 1780.5	C
PIPU-PSME; VAAC Ph.	28	3032.2 ± 2118.8	C
ABCO-PSME; Both Phases	81	2036.9 ± 1677.6	D
ABCO-PSME/ACGL; HODU Ph.	26	2020.7 ± 1446.6	E
ABLA/VASC-LIBO	12	1831.9 ± 886.1	E
ABCO-PSME/QUGA; TYP. PH.	47	1474.4 ± 1073.8	E
ABCO-PSME/ACGL; BERE Ph.	3	966.3 ± 402.9	F

1/ Cubic feet/acre.

2/ Oneway AOV, p = 0.10, LSD multiple range test. Means followed by different letters are significantly different.

Table 4. Mean ten-year periodic annual increment for dominant, codominant, and intermediate Douglas-firs with dwarf mistletoe ratings 0 - 2 by habitat type.

Habitat Type	DOMINANT Mean 1/	N	CODOMINANT Mean	N	INTERMEDIATE Mean	N
ABCO-PSME/ERSU	4.20 ± 1.78 A 2/	25	1.92 ± 1.00 A	20	0.15 ± 0.31 E	266
ABCO-PSME; BERE Ph.	3.81 ± 1.75 AB	18	1.71 ± 0.61 AB	26	0.31 ± 0.37 AB	158
PIPU-PSME; VAAC Ph.	3.49 ± 1.85 B	100	1.91 ± 1.22 A	160	0.24 ± 0.38 D	884
ABLA/VASC-LIBO	3.25 ± 2.25 BC	75	1.52 ± 0.99 BC	75	0.33 ± 0.51 A	234
PIPU-PIEN/ERSU	3.25 ± 1.82 BC	57	1.63 ± 0.79 B	79	0.15 ± 0.22 E	464
PIPU-PIEN/SECA	3.23 ± 1.54 BC	46	1.93 ± 1.01 A	81	0.24 ± 0.37 CD	368
ABCO-PSME/ACGL; HODU Ph.	2.96 ± 2.00 CDE	101	1.34 ± 0.86 CDE	127	0.31 ± 0.50 A	486
ABCO-PSME/QUGA; TYP. Ph.	2.59 ± 1.86 DE	118	1.43 ± 0.77 BD	191	0.23 ± 0.32 D	2127
ABCO-PSME/POFE	2.37 ± 1.10 DE	24	1.34 ± 0.50 BE	16	0.12 ± 0.18 E	249
ABLA/ERSU	2.34 ± 1.70 E	62	1.20 ± 0.92 E	86	0.29 ± 0.33 ABC	189
ABCO-PSME; RONE Ph.	2.21 ± 1.71 E	173	1.16 ± 0.92 E	263	0.24 ± 0.37 CD	1291
ABCO-PSME/ACGL; BERE Ph.	1.93 ± 1.98 E	26	1.27 ± 1.11 CDE	46	0.25 ± 0.33 BD	127

1/ Cubic feet/acre/year.

2/ Oneway AOV, p = 0.10, LSD multiple range test. Means followed by different letters are significantly different.

Table 5. Mean ten-year periodic annual increment for dominant Douglas-firs by habitat type and dwarf mistletoe rating classes.

Habitat Type	DMR Class	Periodic Annual Increment 1/	Number Trees
ABCO-PSME/ERSU	0-2	4.20 ± 1.78 A 2/	25
	3-4	3.67 ± 1.34 B	6
	5-6	1.50 ± 0.99 C	5
ABCO-PSME; BERE Ph.	0-2	3.81 ± 1.75 A	18
	3-4	3.41 ± 3.21 A	3
	5-6	0.87 ± 0.48 B	5
PIPU-PSME; VAAC Ph.	0-2	3.49 ± 1.85 A	100
	3-4	2.92 ± 1.45 B	39
	5-6	2.50 ± 1.78 C	14
ABLA/VASC-LIBO	0-2	3.25 ± 2.25 A	75
	3-4	2.88 ± 1.88 A	18
	5-6	1.57 ± 1.86 B	32
PIPU-PIEN/ERSU	0-2	3.25 ± 1.82 A	57
	3-4	2.35 ± 1.90 B	25
	5-6	1.04 ± 0.59 C	14
PIPU-PIEN/SECA	0-2	3.23 ± 1.54 A	46
	3-4	3.46 ± 1.61 A	11
	5-6	2.05 ± 0.93 B	8
ABCO-PSME/ACGL; HODU Ph.	0-2	2.96 ± 1.99 A	101
	3-4	2.77 ± 1.78 A	24
	5-6	0.96 ± 0.75 B	11
ABCO-PSME/QUGA; TYP. Ph.	0-2	2.59 ± 1.86 A	118
	3-4	2.64 ± 2.50 A	32
	5-6	2.04 ± 2.15 B	16
ABCO-PSME/POFE	0-2	2.37 ± 1.10 A	24
	3-4	2.05 ± 0.83 B	10
	5-6	1.43	1
ABLA/ERSU	0-2	2.34 ± .70 A	62
	3-4	1.98 ± .59 B	35
	5-6	1.05 ± .63 C	40
ABCO-PSME; RONE Ph.	0-2	2.21 ± 1.71 A	173
	3-4	1.62 ± 1.26 B	37
	5-6	0.99 ± 0.96 C	33
ABCO-PSME/ACGL; BERE Ph.	0-2	1.93 ± 1.98 A	26
	3-4	1.71 ± 1.25 A	11
	5-6	0.38 ± 0.13 B	8

1/ Cubic feet/acre/year.

2/ Oneway AOV, p = 0.10, LSD multiple range test. Numbers followed by different letters are significantly different.

Table 6. Mean ten-year periodic annual increment for codominant Douglas-firs by habitat type and dwarf mistletoe rating classes.

Habitat Type	DMR Class	Periodic Annual Increment 1/	Number Trees
PIPU-PIEN/SECA	0-2	1.93 ± 1.01 A 2/	81
	3-4	1.89 ± 0.93 A	9
	5-6	0.80 ± 0.78 A	11
ABCO-PSME/ERSU	0-2	1.92 ± 1.01 A	20
	3-4	2.06 ± 1.59 A	9
	5-6	0.98 ± 0.67 B	15
PIPU-PSME; VAAC Ph.	0-2	1.91 ± 1.22 A	160
	3-4	1.15 ± 0.74 B	22
	5-6	0.81 ± 0.78 C	57
ABCO-PSME; BERE Ph.	0-2	1.71 ± 0.61 A	26
	3-4	1.46 ± 0.31 A	2
	5-6	0.41 ± 0.22 B	6
PIPU-PIEN/ERSU	0-2	1.63 ± 0.79 A	79
	3-4	0.95 ± 0.63 B	27
	5-6	0.74 ± 0.46 B	23
ABLA/VASC-LIBO	0-2	1.52 ± 0.99 A	75
	3-4	1.71 ± 0.83 A	10
	5-6	0.91 ± 0.69 B	19
ABCO-PSME/QUGA; TYP. Ph.	0-2	1.43 ± 0.77 A	191
	3-4	1.20 ± 0.67 B	35
	5-6	0.76 ± 0.50 C	25
ABCO-PSME/ACGL; HODU Ph.	0-2	1.36 ± 0.86 A	127
	3-4	1.43 ± 0.91 A	35
	5-6	0.66 ± 0.39 B	16
ABCO-PSME/POFE	0-2	1.34 ± 0.50 A	16
	3-4	0.89 ± 0.11 B	5
	5-6	0.79 ± 0.11 B	2
ABCO-PSME/ACGL; BERE Ph.	0-2	1.27 ± 1.11 A	46
	3-4	0.63 ± 0.30 B	12
	5-6	0.59 ± 0.47 B	11
ABLA/ERSU	0-2	1.20 ± 0.92 A	86
	3-4	1.02 ± 0.70 A	18
	5-6	0.55 ± 0.37 B	45
ABCO-PSME; RONE Ph.	0-2	1.16 ± 0.92 A	263
	3-4	0.90 ± 0.70 B	74
	5-6	0.46 ± 0.39 C	70

1/ Cubic feet/acre/year.

2/ Oneway AOV, p = 0.10, LSD multiple range test. Numbers followed by different letters are significantly different.

Table 7. Mean periodic annual increment for intermediate Douglas-firs by habitat type and dwarf mistletoe rating classes.

Habitat Type	DMR Class	Periodic Annual Increment 1/	Number Trees
ABLA/VASC-LIBO	0-2	0.33 ± 0.51 2/	234
	3-4	0.26 ± 0.29	15
	5-6	0.22 ± 0.17	52
ABCO-PSME; BERE Ph.	0-2	0.31 ± 0.37	158
	3-4	0.32 ± 0.38	8
	5-6	0.31 ± 0.31	13
ABCO-PSME/ACGL; HODU Ph.	0-2	0.31 ± 0.50	486
	3-4	0.39 ± 0.41	111
	5-6	0.21 ± 0.22	63
ABLA/ERSU	0-2	0.29 ± 0.33	86
	3-4	0.29 ± 0.40	18
	5-6	0.20 ± 0.21	45
ABCO-PSME/ACGL; BERE Ph.	0-2	0.25 ± 0.33	127
	3-4	0.25 ± 0.25	39
	5-6	0.16 ± 0.17	84
PIPU-PIEN/SECA	0-2	0.24 ± 0.37	368
	3-4	0.28 ± 0.24	18
	5-6	0.27 ± 0.34	36
ABCO-PSME; RONE Ph.	0-2	0.24 ± 0.37	1291
	3-4	0.28 ± 0.30	146
	5-6	0.14 ± 0.14	298
PIPU-PSME; VAAC Ph.	0-2	0.24 ± 0.38	884
	3-4	0.28 ± 0.36	82
	5-6	0.21 ± 0.18	94
ABCO-PSME/QUGA; TYP. Ph.	0-2	0.23 ± 0.32	2127
	3-4	0.26 ± 0.33	233
	5-6	0.26 ± 0.32	176
ABCO-PSME/POFE	0-2	0.22 ± 0.18	249
	3-4	0.25 ± 0.34	33
	5-6	0.21 ± 0.21	13
PIPU-PIEN/ERSU	0-2	0.15 ± 0.22	464
	3-4	0.22 ± 0.32	53
	5-6	0.19 ± 0.19	62
ABCO-PSME/ERSU	0-2	0.15 ± 0.31	266
	3-4	0.19 ± 0.25	41
	5-6	0.13 ± 0.33	54

1/ Cubic feet/acre/year.

2/ Oneway AOV, p = 0.10, LSD multiple range test. No results were significantly different between DMR classes.

Table 8. Mean periodic annual increment for dominant and codominant Douglas-firs with dwarf mistletoe rating 0 - 2 by habitat type.

Habitat Type	Mean Periodic Annual Increment 1/	Number Trees	95 Percent Confident Interval
ABCO-PSME/ERSU	3.19 ± 1.86 A 2/	45	2.63 - 3.75
PIPU-PSME; VAAC Ph.	2.52 ± 1.68 B	260	2.32 - 2.73
ABCO-PSME; BERE Ph.	2.47 ± 1.58 BC	47	2.01 - 2.93
PIPU-PIEN/SECA	2.39 ± 1.37 BC	129	2.15 - 2.63
ABLA/VASC-LIBO	2.39 ± 1.94 BC	150	2.07 - 2.70
PIPU-PIEN/ERSU	2.29 ± 1.55 BC	137	2.03 - 2.55
ABCO-PSME/ACGL; HODU Ph.	1.97 ± 1.68 D	240	1.76 - 2.19
ABCO-PSME/POFE	1.96 ± 1.03 CDE	40	1.63 - 2.29
ABCO-PSME/QUGA; TYP. Ph.	1.83 ± 1.41 DE	318	1.67 - 1.98
ABLA/ERSU	1.68 ± 1.42 EF	148	1.45 - 1.91
ABCO-PSME; RONE Ph.	1.53 ± 1.39 F	454	1.40 - 1.65
ABCO-PSME/ACGL; BERE Ph.	1.43 ± 1.50 F	76	1.09 - 1.77

1/ Cubic feet/acre/year.

2/ Oneway AOV, p = 0.10, LSD multiple range test. Means followed by different letters are significantly different.

Table 9. Ten-year annual increment for dominant and codominant Douglas-firs by DMR classes and habitat type.

Habitat Type	DMR Class	Periodic Annual Increment 1/	Number Trees
ABCO-PSME/ERSU	0-2	3.19 ± 1.86 A 2/	45
	3-4	2.95 ± 1.57 A	15
	5-6	1.11 ± 0.77 B	20
PIPU-PSME; VAAC Ph.	0-2	2.52 ± 1.68 A	260
	3-4	2.28 ± 1.50 A	61
	5-6	1.14 ± 1.24 B	71
ABCO-PSME; BERE Ph.	0-2	2.47 ± 1.58 A	47
	3-4	2.63 ± 2.51 A	5
	5-6	0.62 ± 0.42 B	11
PIPU-PIEN/SECA	0-2	2.39 ± 1.27 A	129
	3-4	2.75 ± 1.54 A	20
	5-6	1.32 ± 1.04 B	19
ABLA/VASC-LIBO	0-2	2.39 ± 1.94 A	150
	3-4	2.46 ± 1.67 A	28
	5-6	1.33 ± 1.55 B	51
PIPU-PIEN/ERSU	0-2	2.29 ± 1.55 A	137
	3-4	1.59 ± 1.55 B	53
	5-6	0.85 ± 0.55 C	37
ABCO-PSME/ACGL; HODU Ph.	0-2	1.97 ± 1.68 A	240
	3-4	1.98 ± 1.48 A	59
	5-6	0.78 ± 0.58 B	27
ABCO-PSME/POFE	0-2	1.96 ± 1.03 A	40
	3-4	1.67 ± 0.88 A	15
	5-6	1.01 ± 0.38 B	3
ABCO-PSME/QUGA; TYP. Ph.	0-2	1.83 ± 1.42 A	318
	3-4	1.89 ± 1.95 A	67
	5-6	1.39 ± 1.59 B	41
ABLA/ERSU	0-2	1.68 ± 1.42 A	148
	3-4	1.62 ± 1.43 A	54
	5-6	0.79 ± 0.56 B	85
ABCO-PSME; RONE Ph.	0-2	1.53 ± 1.39 A	454
	3-4	1.14 ± 0.98 B	111
	5-6	0.63 ± 0.67 C	103
ABCO-PSME/ACGL; BERE Ph.	0-2	1.43 ± 1.50 A	76
	3-4	1.15 ± 1.03 AB	23
	5-6	0.50 ± 0.37 B	19

1/ Cubic feet/acre/year.

2/ Oneway AOV, p = 0.10, LSD multiple range test. Means followed by different letters are significantly different.

Table 10. Percent growth loss for dominant and codominant Douglas-firs for DMR classes 3-4 and 5-6 and potential damage ratings by habitat type.

Habitat Type	Percent Growth Loss		Potential Damage Rating
	DMR 3-4	DMR 5-6	
PIPU-PIEN/ERSU	31	63	94
ABCO-PSME/ACGL; BERE Ph.	20	65	85
ABCO-PSME; RONE Ph.	25	59	84
ABCO-PSME; BERE Ph.	0	75	75
ABCO-PSME/ERSU	8	65	73
PIPU-PSME; VAAC Ph.	10	55	65
ABCO-PSME/POFE	15	48	63
ABCO-PSME/ACGL; HODU Ph.	0	60	60
ABLA/ERSU	4	53	57
PIPU-PIEN/SECA	0	45	45
ABLA/VASC-LIBO	0	44	44
ABCO-PSME/QUGA; TYP. Ph.	0	24	24

Table 11. Mean total ten-year periodic annual increment for noninfested plots by habitat type.

Habitat Type	Number of Plots	Mean Total Periodic Annual Increment 1/	Mean Number of Trees Per Plot
ABCO-PSME/ERSU	2	66.3 ± 10.5 A 2/	158.0
ABLA/VASC-LIBO	7	61.1 ± 15.2 A	59.4
ABCO-PSME/ACGL; HODU Ph.	11	58.2 ± 20.5 A	71.6
PIPU-PSME; VAAC Ph.	12	57.5 ± 19.5 A	78.7
ABCO-PSME; BERE Ph.	3	55.4 ± 31.8 AB	88.0
PIPU-PIEN/ERSU	5	51.5 ± 8.2 AB	86.8
PIPU-PIEN/SECA	9	49.9 ± 21.5 AB	51.9
ABCO-PSME/QUGA; TYP. Ph.	23	41.6 ± 11.4 B	100.7
ABCO-PSME/ACGL; BERE Ph.	3	39.2 ± 8.7 B	62.3
ABCO-PSME; RONE Ph.	26	37.5 ± 17.5 B	74.1
ABLA/ERSU	3	35.3 ± 4.2 B	25.0

1/ Cubic feet/acre/year.

2/ Oneway AOV, p = 0.10, LSD multiple range test. Means followed by different letters are significantly different.

Appendix A

Southwestern spruce-fir and mixed conifer forest habitat types sampled.

Spruce-fir Forest Habitat Types:

ABLA/VASC-LIBO: *Abies lasiocarpa/Vaccinium scoparium - Linnea borealis*

ABLA/ERSU: *Abies lasiocarpa/Erigeron superbus*

Mixed Conifer Forest Habitat Types:

PIPU-PIEN/SECA: *Picea pungens - Picea engelmanii/Senecin cardamine*

PIPU-PIEN/ERSU: *Picea pungens - Picea engelmannii/Erigeron superbus*

PIPU-PSME: *Picea pungens - Pseudotsuga menziesii*

VAAC Ph.: *Valeriana acutiloba* Phase

ABCO-PSME/ACGL: *Abies concolor - Pseudotsuga menziesii/Acer glabrum*

BERE Ph.: *Berberis repens* Phase

HODU Ph.: *Holodiscus dumosa* Phase

ABCO-PSME/QUGA: *Abies concolor - Pseudotsuga menziessi/Quercus gambelii*

ABCO-PSME: *Abies concolor - Pseudotsuga menziesii*

BERE Ph.: *Berberis repens* Phase

RONE Ph.: *Robinia neomexicana* Phase

ABCO-PSME/ERSU: *Abies concolor - Pseudotsuga menziesii/Erigeron superbus*

ABCO-PSME/POFE: *Abies concolor - Pseudotsuga menziesii/Poa fendleriana*

Appendix B

Mean total ten-year periodic annual increment for non-infested plots and infested plots by habitat type.

Habitat Type	Mean Total Periodic Annual Increment 1/	Plots
ABCO-PSME/ERSU	66.3 ± 10.5 A 2/, 3/	2
	56.3 ± 21.7 A	6
ABLA/VASC-LIBO	61.1 ± 15.2 A	7
	49.4 ± 22.1 A	11
ABCO-PSME/ACGL; HODU Ph.	58.2 ± 20.5 A	11
	45.5 ± 21.9 A	19
PIPU-PSME; VAAC Ph.	57.5 ± 19.5 A	12
	48.7 ± 22.4 A	24
ABCO-PSME; BERE Ph.	55.4 ± 31.8 A	3
	41.4 ± 29.5 A	5
PIPU-PIEN/ERSU	51.5 ± 8.2 A	5
	44.4 ± 14.6 A	13
PIPU-PIEN/SECA	49.9 ± 21.5 A	9
	41.7 ± 21.9 A	16
ABCO-PSME/QUGA; TYP. Ph.	41.6 ± 11.4 A	23
	31.2 ± 10.5 A	46
ABCO-PSME/POFE	41.2 ± 6.7 A	2
	38.2 ± 5.3 A	4
ABCO-PSME/ACGL; BERE Ph.	39.2 ± 8.7 A	3
	31.2 ± 10.5 A	7
ABCO-PSME; RONE Ph.	37.5 ± 17.5 A	26
	35.4 ± 15.5 A	49
ABLA/ERSU	35.3 ± 4.2 A	3
	34.4 ± 9.8 A	12

1/ Cubic feet/acre/year.

2/ Oneway AOV, p = 0.10, LSD multiple range test. Numbers followed by different letters are significantly different.

3/ First value represents non-infested plots. Second value represents infested plots.

Appendix C

Height-age Linear Regression Analyses

Height-age simple linear regression equations were calculated using dominant, codominant, and intermediate Douglas-firs for each habitat type. Trees between the ages of 20 and 200 years were separated into two groups based on DMR (DMR 0-3 and DMR 4-6) for the analyses. Only data collected in 1980 and 1981 were used because crown classes were not recorded in 1979.

The calculated slopes and intercepts of the height-age regression lines were compared using a t-test[1]. Comparisons were made among habitat types within DMR classes 0-3 and 4-6. Comparisons were also made for each habitat type by DMR classes 0-3 and 4-6.

Results

Comparisons of slopes within DMR classes yielded significant differences between several of the habitat types (Table 1C). The slopes were found to be significantly different between DMR classes 0-3 and 4-6 for the following habitat types: ABCO-PSME/ACGL; HODU Ph., ABCO-PSME/POFE, ABCO-PSME; RONE Ph., and PIPU-PIEN/SECA. The slope of the first three habitat types was found to be lower for DMR class 4-6. However, the PIPU-PIEN/SECA habitat type had a higher slope for DMR class 4-6.

Heavy dwarf mistletoe infection reduced the value of the Y-intercept for several of the habitat types (Table 1C), but statistical comparisons between Y-intercepts were not completed.

Discussion

Several workers have shown that height-age relationships are significantly different between habitat types (Daubenmire 1961, Deitschman and Greene

[1] Zarr, G.H. 1974. *Biostatistical Analysis.* Prentice Hall Publ., Inc., Inglewood Cliffs, N.J., p. 292-298.

1965, Stage 1975, Hoffman 1976). Our analyses of height-age relationships for Douglas-fir in different habitat types supports the results of these earlier studies. Because height-age relationships vary greatly between habitat types, separate site index curves should be constructed for different habitat types (Daubenmire 1961, Hoffman 1976), which should improve the accuracy of using site index as an indicator of site quality.

It has often been demonstrated that dwarf mistletoe infection reduces height growth of heavily infected trees (Hawksworth and Scharpf 1978). Because the effect of mistletoe infection on height growth can vary with site quality (Pierce 1960, Parmeter 1978), habitat type could potentially influence the effects of mistletoe infection on height growth. Our results indicate that heavy mistletoe infection has significantly greater effects on Douglas-fir height growth in different habitat types, and therefore, heavy infection levels can potentially have larger impacts on productivity in certain habitat types.

Because site index is based on height-age relationships, there should be a high correlation between high mean site index and height growth rates for habitat types. Comparison of site index and height-age regressions indicates there was a fairly good correlation between site quality indicators for most of the habitat types sampled in this study.

The use of simple linear regression to predict height growth from age is not the most appropriate method because height growth over time does not follow a discrete linear pattern (Brickell 1968, Husch et al. 1972, Curtis et al. 1974, Stage 1975). However, as Hoffman (1976) suggests, linear regression does demonstrate the basic height-age relationship and significant differences between regression equations indicates definite differences in height growth rates between different species, habitat types, and dwarf mistletoe infection classes.

Table 1C

Height/Age Regressions For All Plots by Habitat Type

Habitat Type	N[1]	I[2]	R^2	SLP[3]	N	I	R^2	SLP
ABCO-PSME/ACGL; HODU Ph.	359	16.9	.463	.499A	82	19.8	.396	.423B
ABCO-PSME/POFE	85	0.9	.791	.637A	23	-3.9	.862	.622B
PIPU-PIEN/SECA	208	8.8	.663	.521A	46	-8.4	.843	.647B
PIPU-PSME	438	13.0	.577	.414A	140	13.9	.511	.352A
PIPU-PIEN/ERSU	233	1.6	.667	.515A	95	-10.2	.596	.540A
ABCO-PSME/QUGA; TYP Ph.	820	7.5	.528	.578A	168	2.8	.632	.538A
ABCO-PSME/ERSU	110	-0.5	.696	.676A	50	-5.8	.681	.604B
ABCO-PSME; RONE Ph.	672	15.9	.434	.323A	204	13.9	.350	.280A
ABLA-ERSU	91	7.9	.387	.383A	65	3.2	.335	.358A
ABLA/VASC-LIBO	151	2.7	.495	.409A	61	2.6	.507	.375A

[1] N = number of trees.

[2] I = intercept

[3] SLP = slope

[4] When reading across the table slopes followed by different letters are significantly different.

Figure Captions

Figure 1. Mean Douglas-fir site indexes for several southwestern habitat types. Numbers between bars represent mean site indexes. Bars represent 95 percent confidence intervals. Numbers in brackets represent number of stands sampled.

Figure 2. Estimated yield capabilities for Douglas-fir in several southwestern habitat types based on ten-year periodic annual increment of dominant and codominant trees. Numbers between bars represent mean ten-year periodic annual increment. Bars represent 95 percent confidence intervals. Numbers in brackets represent number of stands sampled.

Figure 3. Estimated yield capabilities for Douglas-fir for several southwestern habitat types based on total ten-year periodic annual increment. Numbers between bars represent mean total ten-year periodic annual increment. Bars represent 95 percent confidence intervals. Numbers in brackets represent number of stands sampled.

FIGURE 1.

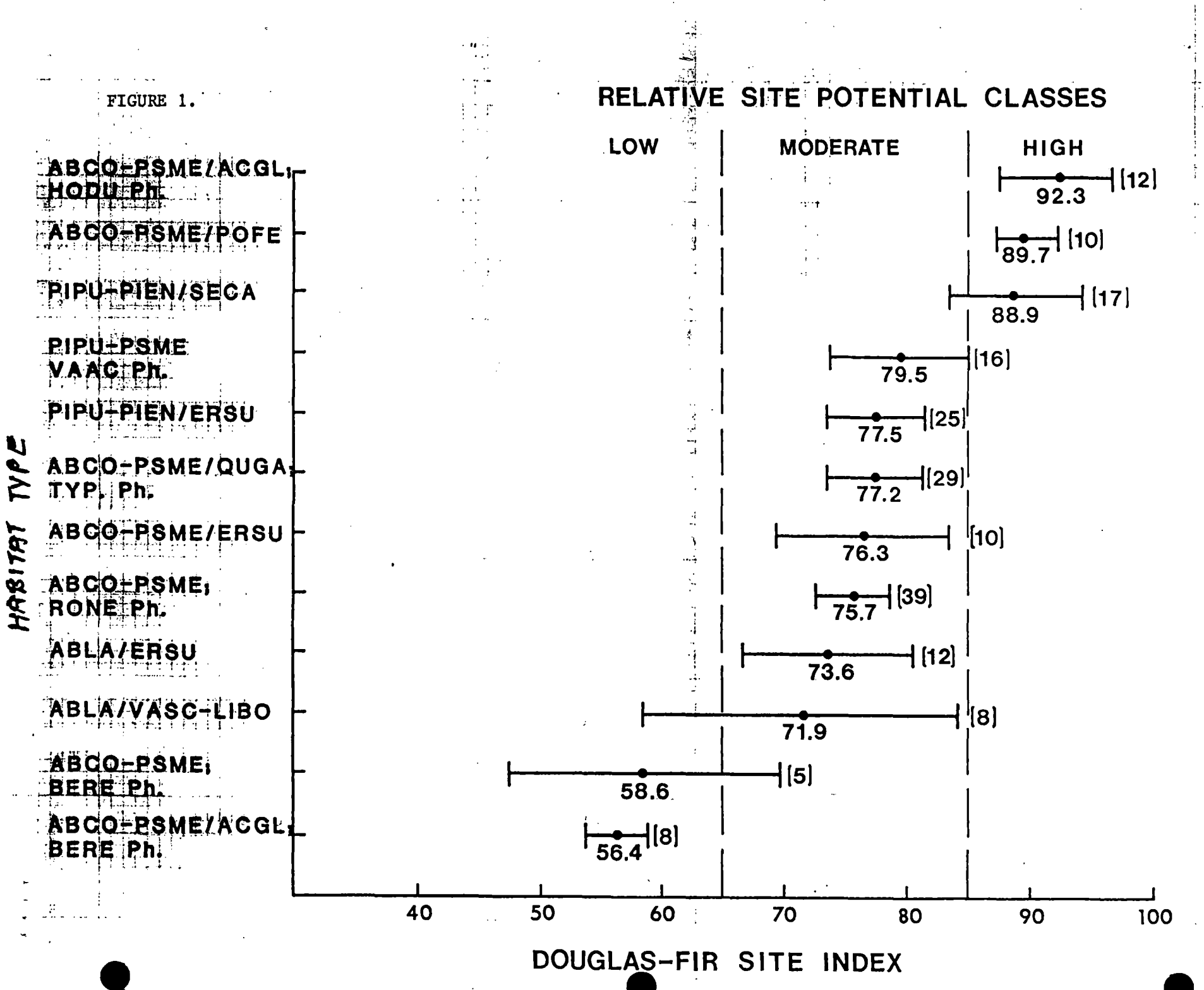

RELATIVE SITE POTENTIAL CLASSES
LOW
MODERATE
HIGH
HABITAT TYPE
ABCO-PSME/ACGL, HODU Ph.
ABCO-PSME/POFE
PIPU-PIEN/SECA
PIPU-PSME VAAC Ph.
PIPU-PIEN/ERSU
ABCO-PSME/QUGA, TYP. Ph.
ABCO-PSME/ERSU
ABCO-PSME; RONE Ph.
ABLA/ERSU
ABLA/VASC-LIBO
ABCO-PSME; BERE Ph.
ABCO-PSME/ACGL, BERE Ph.
92.3 [12]
89.7 [10]
88.9 [17]
79.5 [16]
77.5 [25]
77.2 [29]
76.3 [10]
75.7 [39]
73.6 [12]
71.9 [8]
58.6 [5]
56.4 [8]
40
50
60
70
80
90
100
DOUGLAS-FIR SITE INDEX

FIGURE 2.

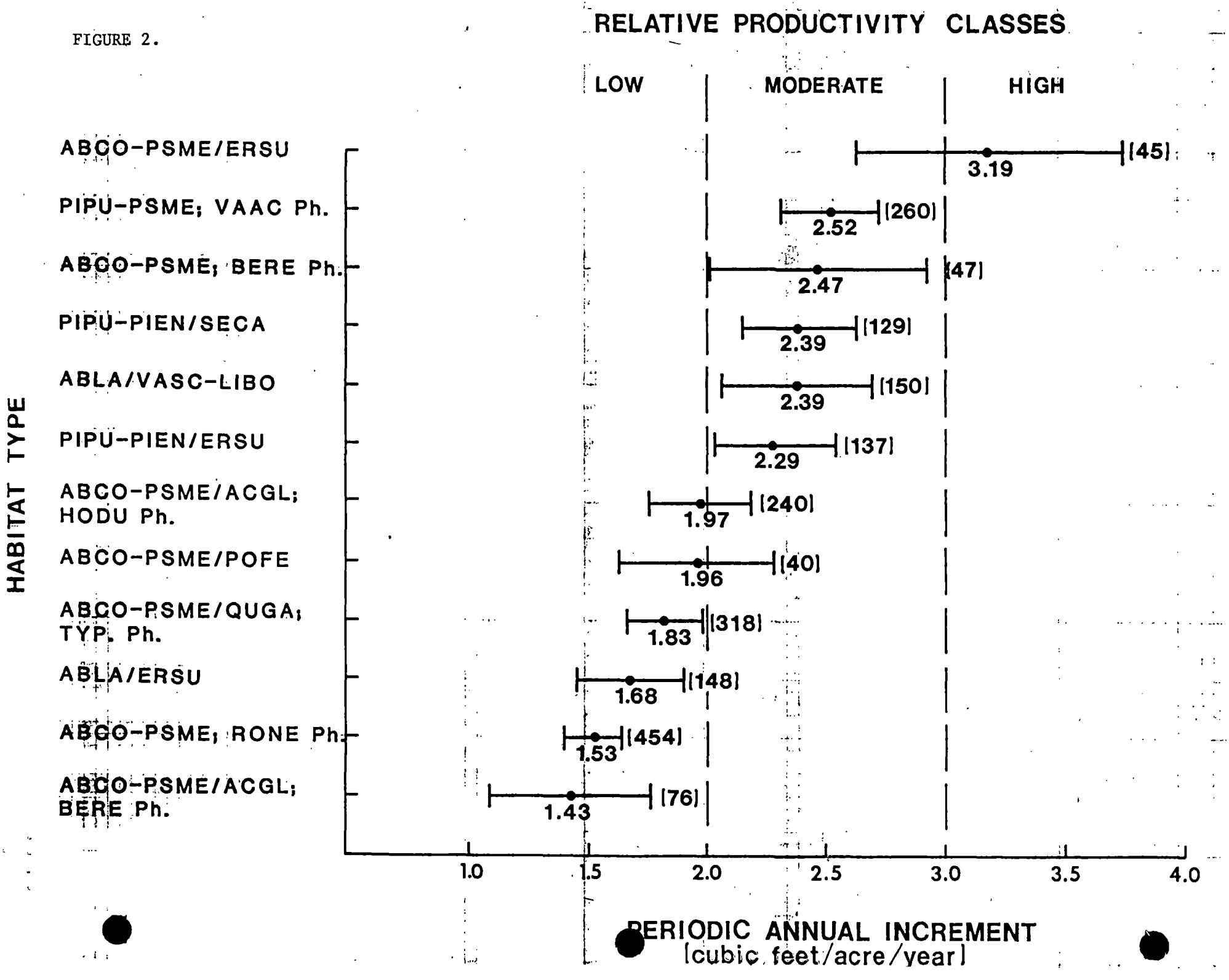
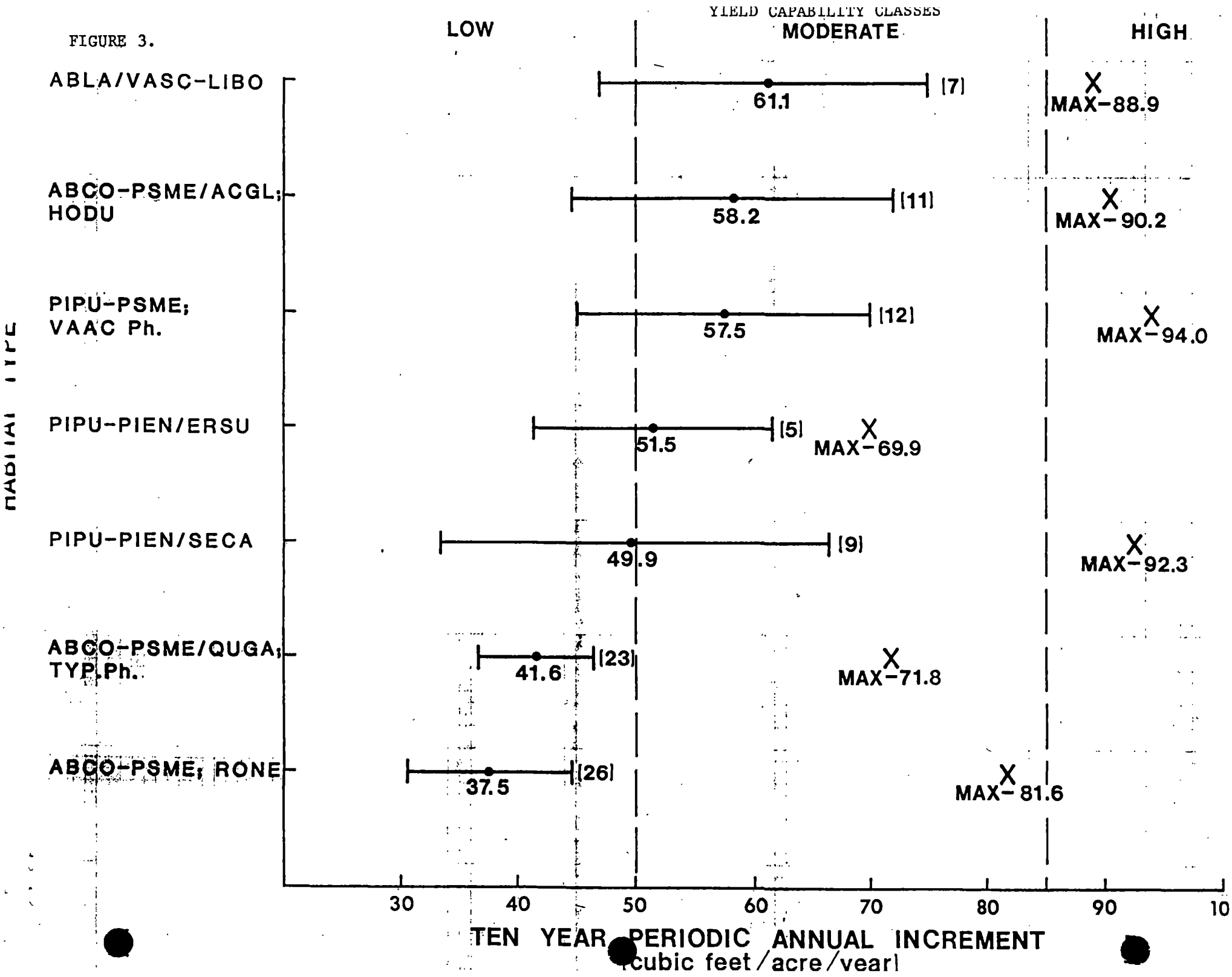

RELATIVE PRODUCTIVITY CLASSES
LOW
MODERATE
HIGH
HABITAT TYPE
ABCO-PSME/ERSU
3.19
[45]
PIPU-PSME; VAAC Ph.
2.52
[260]
ABCO-PSME; BERE Ph.
2.47
[47]
PIPU-PIEN/SECA
2.39
[129]
ABLA/VASC-LIBO
2.39
[150]
PIPU-PIEN/ERSU
2.29
[137]
ABCO-PSME/ACGL; HODU Ph.
1.97
[240]
ABCO-PSME/POFE
1.96
[40]
ABCO-PSME/QUGA; TYP. Ph.
1.83
[318]
ABLA/ERSU
1.68
[148]
ABCO-PSME; RONE Ph.
1.53
[454]
ABCO-PSME/ACGL; BERE Ph.
1.43
[76]
1.0
1.5
2.0
2.5
3.0
3.5
4.0
PERIODIC ANNUAL INCREMENT
[cubic feet/acre/year]

FIGURE 3.


YIELD CAPABILITY CLASSES
LOW
MODERATE
HIGH
ABLA/VASC-LIBO
61.1
[7]
MAX-88.9
ABCO-PSME/ACGL; HODU
58.2
[11]
MAX-90.2
PIPU-PSME; VAAC Ph.
57.5
[12]
MAX-94.0
PIPU-PIEN/ERSU
51.5
[5]
MAX-69.9
PIPU-PIEN/SECA
49.9
[9]
MAX-92.3
ABCO-PSME/QUGA; TYP.Ph.
41.6
[23]
MAX-71.8
ABCO-PSME; RONE
37.5
[26]
MAX-81.6
30
40
50
60
70
80
90
10
TEN YEAR PERIODIC ANNUAL INCREMENT
(cubic feet/acre/year)